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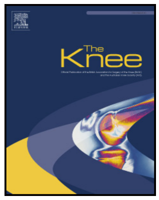

Can kinematic tibial templates assist the surgeon locating the flexion and extension plane of the knee?

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ABSTRACT

Purpose: We performed virtual feasibility and in-vivo validation studies to test whether the use of a kinematic tibial template (KTT) assists the surgeon in accurately locating the orientation of the F-E of the knee with low bias and high precision.

Methods: With use of 166 3-dimensional bone models of normal knees, we designed seven KTTs that located the orientation of the F-E plane of the knee when best-fit within the cortical edge of the tibial resection. The virtual feasibility study asked 11 evaluators with different levels of surgical experience to use software and select, orient, and best-fit the KTT within the tibial resection of each bone model. The in-vivo validation study analyzed tibial component rotation on postoperative CT scans of 118 consecutive patients after one surgeon set the I-E rotation of the tibial component with a KTT when performing kinematically-aligned TKA. Bias and precision were computed as the mean and standard deviation of the differences between the A-P axis of the KTT and the F-E plane of the knee.

Results: For the virtual feasibility study, the bias was 0.7° external and the precision was ±4.6° for 1826 KTT fittings, which were not affected by the level of surgical experience. For the in-vivo validation study, the bias was 0.1° external and the precision was ±3.9°.

Conclusions: The virtual feasibility and in-vivo validation studies suggest a KTT can assist the surgeon in accurately setting the I-E rotation of the tibial component parallel to the F-E plane of the knee when performing kinematically-aligned TKA.

1. Introduction

Correct positioning of the femoral and tibial components is essential for a successful total knee arthroplasty (TKA). Malalignment of the femoral component alters both tibiofemoral and patellofemoral and is responsible for a certain proportion of TKA failure [1]. Malrotation of the tibial component of greater than 10° from the anteroposterior (A-P) axis of the femoral component is associated with persistent pain and poor patient reported satisfaction and functional outcome [2–4].

Current methods used in mechanically aligned TKA for setting the internal-external (I-E) rotation of the tibial component have some subjectivity and are prone to some inaccuracies which can be quantified by bias and precision. For example, a bias up to 25° internal and a precision (standard deviation) of ±10° to 28° from the intended target was reported when eleven arthroplasty surgeons selected the orientation of tibial reference lines connecting the medial border, medial 3rd and anterior crest with the center of the posterior cruciate ligament (PCL) to set I-E rotation of the tibial component [5]. Thus, a method that can assist the surgeon

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in setting I-E rotation of the tibial component with less bias and more precision (i.e. smaller standard deviation) might be of interest.

Kinematically aligned TKA is gaining interest because two level-one randomized trials and national multicenter study showed that patients treated with kinematically aligned TKA reported significantly better pain relief, function, flexion, and a more normal feeling knee than patients treated with a mechanically aligned TKA [6–8]. Kinematically aligned TKA has different targets for aligning a knee, which are to co-align the flexion-extension (F-E) axes of the tibia and patella in the femur and the longitudinal rotation axes in the tibia of the native knee with the axes of the implants [9–12]. Aligning the distal and posterior surface of the femoral component coincident to the native joint lines restores these kinematic axes. Varus-valgus deformities are corrected with a distal referencing guide with a 2 mm offset that compensates for the thickness of the worn cartilage that averages two millimeters on the distal medial and distal lateral femoral condyle in many knees with varus and valgus deformities, respectively [13–15]. Correction for cartilage wear posterior and femoral bone wear at 0 and 90 degrees of flexion is infrequent as most knees with Kellgren-Lawrence Grade 3 or 4 osteoarthritis have <1 mm of wear [15].

Restoring the native joint lines and alignments of the limb and knee to those of the pre-arthritic or native knee co-aligns the components with the kinematic axes (Figure 1) [6,7,13,14,16]. Unlike mechanically aligned TKA, the target for setting the I-E rotation of the tibial component in kinematically aligned TKA is parallel to the F-E plane of the knee. The F-E plane of the knee is oriented perpendicular to lines coincident with the distal and posterior joint lines of the native femur [14,17,18].

Kinematically aligned TKAs have high function when the I-E rotation of the tibial component is set between −11° internal to 12° external from the F-E plane of the knee [19]. Unfortunately the use of the medial border, medial 3rd, and anterior crest of the tibial tubercle is prone to error in locating the orientation of the F-E plane because of the high variability of the medial-lateral position of the tibial tubercle [20]. Therefore, we designed a kinematic tibial template (KTT) and developed a novel method to assist the surgeon in locating the orientation of the F-E plane of the extended knee (Figure 2).

The present study answered two questions: 1) Does a virtual feasibility study show that eleven observers with three different levels of training that select the best fit KTT within the cortical edge of the tibial resection accurately locate the F-E plane of the knee with low bias and high precision? 2) Does an intraoperative analysis show that the best fitting of a KTT by one surgeon accurately set the A-P axis of the tibial component parallel to the F-E plane of the knee with low bias and high precision?

2. Materials and methods

Two independent research settings were used to answer each question: a virtual feasibility study and an intra-operative validation study. All procedures performed in each research setting were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards and were approved by an institutional review board (IRB ID:801079-1, University of CA at Davis).

2.1. Virtual feasibility study

2.1.1. Selection of subjects and design of the kinematic tibial template

One hundred and sixty-six, 3-dimensional bone models of the extended knee were reconstructed from 99 magnetic resonance imaging (MRI) scans and 67 computer tomographic (CT) scans from subjects with normal knees on imaging. Bone models derived from MRI data were previously segmented for a soft tissue and cartilage study. CT scans were randomly selected from TKA patients whose contralateral knee showed no signs of degenerative arthritis. The mean age of the subjects was 63 years old

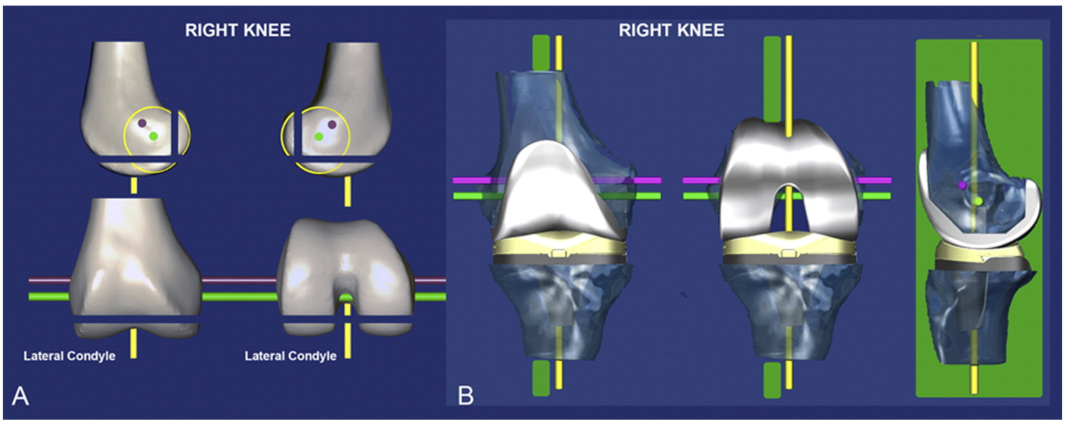

Figure 1. A. The flexion axis of the tibia is the transverse green line, the flexion axis of the patella is the transverse magenta line, and the rotational axis of the tibia is the vertical yellow line. B. The flexion-extension plane of the extended knee (50% opaque green rectangles) lies perpendicular to the native distal and posterior femoral joint lines and the flexion axes of the tibia and patella.

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